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INSECTS, BOTH HOSTS AND VECTORS OF PLANT VIRUSES[1]

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Man, in his attempts to explain the observed phenomena of nature, travels from naive conjectures to the complexities of experimental facts and then seeks generalized simplicity. In the field of virus research we are still in the complex stage in which every generalization proposed has at least one Achilles Heel. A Newton of viruses has not yet appeared on the horizon. Nevertheless, the chase is on and in scores of laboratories throughout the world the quarry is being glimpsed at closer and closer, though still distant, range. Most avidly pursued of all is tobacco mosaic virus which must scarcely dare call its nucleic acid its own.

Among the most complex and least understood of the plant viruses are those which rely heavily or exclusively on insects for their dissemination in nature. The relationships of viruses to their vectors have been studied by a relatively small group of research workers. Yet evidence is accumulating that the insect vector, far from being merely a "flying needle" contaminated with virus, as some have been inclined to consider it, may prove to be the pristine host of some, if not all, plant viruses.

I should like to review some of the more interesting discoveries and hypotheses involving vector-virus relationships, particularly the recent ones and those dealing primarily with the leafhopper transmitted viruses.

Some important discoveries have been made accidentally or as by-products of planned investigations; others have required the penetrating thought and imagination so perceptively described by Schopenhauer (and recently quoted by a colleague) when he said: "Thus the task is, not so much to see what no man has seen yet, but to think what nobody has thought yet, about that which everybody sees."

Why is a Vector a Vector?

The vast majority of known plant virus vectors are insects. Eriophyid mites are also proving to be important vectors of a

[1] Presidential address, presented to the Pacific Coast Entomological Society, December 13, 1958.

few viruses in recent years. This year for the first time, a non-arthropod was demonstrated to transmit a plant virus when Hewitt *et al.* (1958) reported *Xiphinema index* Thorne and Allen, a plant parasitic nematode, to be a vector of grape fan leaf virus.

One of the basic questions in vector-virus relationships, and one about which we are still almost completely ignorant, concerns the factors which govern the transmissibility of viruses by vectors. The vectors of most plant viruses show general but not inflexible phylogenetic affinities. Thus, aphid-transmitted viruses have not been shown conclusively to be transmitted also by leafhoppers, beetles or other insect groups. Viruses associated with leafhoppers are transmissible only by leafhoppers—except in the case of Pierce's disease virus of grapes which is carried by spittle bugs of the family Cercopidae and by sharpshooters in the family Cicadellidae, but not by other leafhoppers. The common denominator among all the vectors of this virus is their habit of feeding in the xylem rather than the phloem of the plants.

There appears to be less group specificity among the vectors of animal viruses. For example, the experimental vectors of the virus causing western equine encephalitis include ticks as well as mosquitoes.

Bennett and Wallace (1938) have shown that the curly top virus of sugar beets, transmitted in the United States only by *Circulifer tenellus* (Baker), can be acquired and carried in the bodies of aphids, mites, thrips and other leafhoppers for long periods of time, but is not transmitted by these species.

The specific cause for failure of a virus to be transmitted by non-vector species or by a genetic strain of its normal vector has been demonstrated only once. Storey (1939) bred a strain of *Cicadulina mbila* (Naudé) which consistently failed to transmit maize streak virus in Africa. However, these "inactive" individuals could be made active vectors if, after they had fed on a diseased plant, the stomach wall of the insects was punctured with a fine needle to permit some of the infective plant juice to enter the blood in the body cavity. This showed that the barrier to virus passage existed in the wall of the intestine.

Present evidence suggests that the constitutional stability of insects as vectors of plant viruses is much greater than are the viruses which they transmit. However, this does not imply that

vector species are homozygous in this respect and show uniformity and consistency in transmitting ability.

Björling and Ossiannilsson (1958) have just published the results of extensive experiments involving 10 asexually reared strains of six different species of aphids as vectors of two persistent viruses, beet yellows and potato leaf roll. The aphids were: *Myzus persicae* (Sulzer), *M. ascalonicus* Doncaster, *Aphis fabae* Scopoli, *Aulacorthum circumflexum* (Buckton), *A. solani* Kaltenbach) and *Macrosiphum euphorbiae* (Thomas). Nearly all of the strains of *Myzus persicae* were better vectors of both potato leaf roll and beet yellows virus than were the best strains of the other aphid species compared.

Most of the work dealt with 85 strains of *Myzus persicae* which had been collected from widely different geographical and ecological sources. Virus transmission tests over a three year period revealed that these 85 strains could be grouped in a continuous series which ranged from 10 per cent to 80 per cent in virus transmitting ability. Moreover, there was no correlation between the field source plant of the aphid strain, nor the plants on which the aphids fed just prior to being used in virus tests, and their efficiency as vectors.

Most of the strains were fairly efficient vectors with individual aphids of 70 of the 85 strains transmitting beet yellows virus to 30 per cent or higher of the test plants. The absolute differences in transmission efficiency were great between some strains and significant in a number of cases. The authors were led to conclude that "these differences between more or less effective vector strains within the same species seem to be genetically determined." This was also supported by tests in which two aphid strains of similar vector efficiency were crossed. The efficiency of the progeny was markedly below that of the parents.

Loss and Recovery of Insect Transmissibility by Viruses

There is now considerable evidence that the insect transmissibility of many plant viruses is not constant, but varies sometimes in relatively short periods of time. For many years it has been the not uncommon experience of those who work with insects and viruses to find that known vectors of certain viruses sometimes transmit them inefficiently or not at all. Very often this is encountered after an interruption of transmission work for several months or years. It is apparently often due to a reduction in virus

titre in a plant which has been infected for an extended period of time. However, in other instances it may occur with viruses whose titre has been maintained at a high level by frequent transmission to new plants or animals by means of mechanical inoculation.

Transmissibility by mosquitoes of certain strains of yellow fever, encephalitides and dengue viruses is greatly reduced or eliminated after repeated passage by mechanical means in the vertebrate hosts (Reeves, 1958).

Viruses are known to mutate and it is probable that vectorless mutants may appear which, in the absence of insect transmission, might supplant the insect transmissible virus strain.

Black (1953) maintained three isolates of potato yellow dwarf virus for 12-16½ years in plants without insect transmission. At the end of this period the leafhopper vector was unable to transmit these isolates whereas control leafhoppers transmitted fresh isolates of the virus, collected in the field, with normal high frequency. Very recently Black *et al* (1958) reported the same phenomenon for wound-tumor virus and its leafhopper vector.

Similar loss of transmissibility by aphids was reported by Hollings (1955) for tomato aspermy virus. One isolate, at first easily transmitted by aphids, was transmitted only with great difficulty by vectors after two years of mechanical transmission to tobacco.

I worked with an aphid transmissible virus of garden nasturtium, *Tropaeolum majus*, over a period of several years. Vector work was then discontinued for approximately two years during which the virus was transmitted by juice inoculation every few months. When aphids were tried again as vectors transmission occurred only rarely. Field collected *Myzus persicae* were also tried as vectors but they succeeded no better than did our greenhouse colonies.

In the above cases loss of transmissibility by insects followed two or more years of virus maintenance or transmission in the absence of insects. Swenson (1957) reported that one of two isolates of bean yellow mosaic virus lost its ability to be transmitted by three species of aphids within a period of one to four months.

The most obvious explanation suggested by these results is that the virus isolates in question lost their ability to be trans-

mitted by their normal vectors as a result of mutations of the virus. Since the tomato aspermy virus isolate became almost completely vectorless in a two-year period it may be inferred that the alleged mutant strain was replacing the insect transmitted strain gradually. In contrast to this, however, is the fact that Swenson's bean virus apparently became completely vectorless within one to four months after having been transmitted readily by three species of aphids.

That the apparent loss of insect transmissibility by a virus may be reversible has been reported by Watson (1956, 1958). Potato virus C, derived from potatoes, was not transmissible by aphids. However, after mechanical inoculation into *Nicotiana glutinosa* this virus could be transmitted by *Myzus persicae*. When returned to potato by means of aphids, the virus ultimately reverted to the vectorless strain although certain isolates remained aphid transmissible through several passages in potato.

The first speculative explanations suggested by this phenomenon were of two different types. One involved possible mutations; the other required a quantitative rather than a qualitative hypothesis and postulated vectorial and vectorless virus particles which varied in ratio in the different hosts. Each of these hypotheses required assumptions that are without precedent.

What may prove to be a more plausible explanation has just been reported. Badami and Kassanis (1958) obtained a strain of potato virus Y, from *Solanum jasminoides* from India, which in potato closely resembled the potato virus C used by Watson. However, after separation from two other viruses which were also present in *S. jasminoides*, this virus was readily transmitted by *Myzus persicae*. These previously undescribed viruses are reported to decrease the multiplication of the virus Y strain and also its aphid transmissibility.

This suggests that Watson's potato virus C may not be aphid-transmissable from potato because of the possible presence in potato of another virus which reduces or prevents transmission of virus by aphids. Tobacco may not be a host of this virus and thus virus C would be available for transmission by aphids.

This phenomenon is just the opposite of that reported by Smith (1945) for the virus complex known as tobacco rosette. One component, mottle virus, is easily transmitted mechanically but

cannot be transmitted by *Myzus persicae* unless it occurs in the same plant which carries vein-distorting virus.

Cross Protection Between Viruses in Insects

Although plants are not known to produce antibodies to infective disease agents such as we know to be common in animals, plants, after infection by a virus, may acquire immunity to related and sometimes more virulent strains of the same virus. The different strains have been assumed to arise through mutation, but there is now evidence that genetic recombination may also be involved. The ability of one virus strain to prevent a second strain from producing its own characteristic disease symptoms in the same plant has been considered evidence that the two strains are closely related. However, it is also possible to have closely related strains, such as those of curly top virus of sugar beets, which do not protect against each other either in the plant or in the insect vector (Giddings, 1950).

Kunkel (1955) showed that the California and the eastern U.S. strains of aster yellows virus protect against each other in some of their common host plants. He also obtained evidence that the same strains protect against each other in the aster leafhopper, *Macrosteles fascifrons* (Stål). Working with groups of leafhoppers, he found that those which fed for two weeks on plants infected with one strain of virus and then fed two weeks on plants carrying the other virus strain, always transmitted only the first strain.

Experiments of several different types have demonstrated that aster yellows virus multiplies in the aster leafhopper as well as in the plant. Although the mechanism of cross protection among viruses is not known, it has been inferred that related strains need the same materials for multiplication and that the first virus to invade a host occupies the sites of virus multiplication and uses up the materials available, thus denying to the challenging strain the products it needs for multiplication.

However, more extensive experiments by Freitag (1958) in California with three strains of aster yellows virus and the aster leafhopper have shown that cross protection is not always stable and permanent. Working with single insects and transferring them daily over long periods of time, he found that under some circumstances the leafhoppers finally stopped transmitting the first strain acquired and then transmitted the challenging strain. These were,

however, exceptional cases. In most instances there was marked cross protection in both insect and plant.

Maramorosch (1957, 1958a) has reported the same phenomenon with two strains of corn stunt virus and its vector *Dalbulus maidis* (DeLong & Wolcott). In the studies conducted with aster yellows virus and with corn stunt virus, one strain in each disease complex showed greater dominance than the other in both the insect vector and the host plant. In the leafhoppers, strain "A", acquired first, was sometimes replaced by strain "B". However, if strain "B" was acquired first, strain "A" failed to supplant it. This indicates that the phenomenon of cross protection is more complex than mere prior occupancy of virus multiplication centers in the insect or plant by the first strain to enter.

Our perplexity regarding the nature of this apparent competition between plant virus strains within the body of the leafhopper vector is compounded by the nature of strain replacement in the insect. In a few instances, test plants fed on by single insects showed symptoms of both virus strains. In most cases, however, symptoms were entirely of one strain or the other. Also, replacement of one strain by a more dominant strain within the same leafhopper was not always permanent when first accomplished. Sometimes the strains were transmitted alternately before the dominant strain finally completely supplanted the other.

The presence and multiplication of two virus strains in the same leafhopper vector have not yet been known to result in a new hybrid virus. However, more extensive tests involving related virus strains carried by the same vectors might produce new hybrid plant viruses in insects as it has in plants and in vertebrate animals.

Recombinations of genetic units between related strains of animal and plant viruses have already been reported. The first work of this type was done by Burnet and Lind (1951) with strains of influenza virus. Subsequently, Best and Gallus (1955) and Best (1956) achieved similar results with tomato spotted wilt virus. Plants infected with mixtures of two strains of this virus developed symptoms of both parent strains and also symptoms of new strains. From these plants with mixed infections they recovered both parent strains and also several new strains. The latter were distinct from each of the parent strains but possessed some of the characters of each parent. Further experiments led

to the conclusion that such new strains were genetically stable and not mere mixtures of the two parent strains.

It would be of great interest to determine if parallel results could be obtained by allowing the thrips vector to acquire two or more of these same strains of spotted wilt virus. Multiplication of spotted wilt virus in thrips has not yet been demonstrated, but the 5–10 day incubation period of the virus in the vector, plus long retention of the virus by the vector, suggest multiplication.

Beneficial Effects of Plant Virus in Relation to Insect Vectors

A few reports exist indicating that a plant virus may be of indirect benefit to its own insect vector or to a non-vector species. Carter (1939) found that infected *Emilia sonchifolia*, a weed host of both spotted wilt virus and its vector *Thrips tabaci* Lindeman, maintained a higher population of thrips than did healthy plants. The reasons for this appeared to be that diseased plants had curled leaves which provided improved shelter for the thrips vector and that these plants also grew more slowly and survived longer.

A more direct beneficial effect of virus on *Aphis fabae* has been reported by Kennedy (1951). He found that sugar beet mosaic virus altered the physiology of the beet plant in such a manner that the production of young aphids per mother averaged higher on virus infected leaves of all ages than on healthy leaves of comparable age.

Severin (1946), incidental to his search for new leafhopper vectors of aster yellows virus, found that 9 species of leafhoppers completed their nymphal development on celery or asters infected with California aster yellows virus, but that the adults died within a few days after transfer to healthy celery or asters. No data were presented on the longevity of any control adults that may have been held on diseased plants. The results given were interpreted as demonstrating that aster yellows virus in some way altered celery and aster plants so as to make them more suitable food hosts for the leafhopper species tested.

Maramorosch (1958b) reported similar conclusions drawn from experiments with *Dalbulus maidis* (DeLong & Wolcott), a non-vector of aster yellows virus. This leafhopper, which transmits corn stunt virus, was known to feed well and breed only on *Zea mays* and *Euchlaena mexicana*. Eighty adult insects were caged on healthy China asters and 80 were caged on asters infected with

aster yellows virus. All insects on healthy asters were dead within four days, but 63 of 80 were still alive on virus-infected plants after 42 days. The survival on diseased asters was practically identical with the survival on corn plants but no eggs were deposited in the aster plants. In subsequent tests *D. maidis,* after five weeks on infected asters, were successfully maintained on healthy asters. Adults and nymphs of a related leafhopper, *D. elimatus* (Ball), with a limited host range identical to that of *D. maidis,* were found to survive well on asters carrying virus, but died rapidly on healthy asters. Maramorosch interprets his experiments as indicating that the virus altered the chemical composition of the aster plant in the direction of more adequate nutrition for the leafhoppers which, in the case of *D. maidis,* became sufficiently adapted to aster as to permit survival even on virus-free asters.

Among the species discussed by Severin (1946) in his report on the longevity of leafhoppers on virus-infected and healthy plants was *Texananus spatulatus* Van Duzee. He stated that individuals of this species which transmitted aster yellows virus lived longer than those which failed to transmit virus. Only a small part of the data on which this conclusion was based has been published (Severin, 1945). Since the virus transmitting efficiency of this species was exceedingly low (most individuals carrying virus infected less than one percent of the plants fed upon) and since it is not clear whether the transmitters and the non-transmitters were maintained in the same manner, further confirmation is needed for the generalization that the transmitting insects lived longer than the non-vectors. Severin construed the increased longevity to mean that the plants infected were better hosts and prolonged the life of the leafhoppers. However, since the insects were transferred daily to new test plants and transmitted virus to only a few plants this explanation does not seem feasible. If the transmitting insects lived significantly longer than non-transmitters, it would be evidence that the virus *per se* was beneficial to the insect.

No reports, parallel to those given for plant viruses, have been found to indicate that animal viruses may render their hosts suitable as food sources for arthropods if, in the absence of virus, such hosts are unacceptable to the arthropod species. Virus-infected animals sometimes carry abnormally high populations of arthropod parasites but apparently this is only because such animals become

debilitated and therefore are less capable of ridding themselves of the parasites than are healthy individuals.

In none of the situations just described was it suggested by the research workers involved that the virus itself contributed directly to the increased longevity of the insect vector.

A Virus Harmful to Both Animal and Plant

Although there have been many insect-borne plant viruses known and a less lengthy list of insect-borne animal viruses, until recently there has been no report of a virus that was harmful to its insect vector.

It is true that we have such an example among the rickettsiae, some of which have also been called viruses, but Snyder (1948) classes these as "micro-organisms . . . intermediate in characteristic between bacteria and viruses . . ." The body louse, vector of typhus fever rickettsiae, is also killed by the infectious agent it carries. Zinsser (1935), describes the plight of the body louse in these words: "The louse shares with us the misfortune of being prey to the typhus virus. If lice can dread, the nightmare of their lives is the fear of some day inhabiting an infected rat or human being. For the host may survive; but the ill-starred louse that sticks his haustellum through an infected skin, and imbides the loathsome virus with his nourishment, is doomed beyond succor. In eight days he sickens, in ten days he is *in extremis*, on the eleventh or twelfth his tiny body turns red with blood extravasated from his bowel, and he gives up his little ghost."

The first indication that a plant virus could cause tissue changes in its insect vector was given by Littau and Maramorosch (1956). They reported that aster yellows virus caused a higher percentage of fat body cells to have stellate nuclei than occurred in virus-free *Macrosteles fascifrons* (Stål). There is as yet, however, no evidence that these effects are harmful to the leafhopper.

The effect of aster yellows virus on the longevity of this vector was tested extensively by Severin (1947). Both infective and non-infective leafhoppers were held on Sacramento barley, which is immune to the virus, and survival was recorded. Adult longevity ranged from approximately 30 days to over 140 days. The 350 infective leafhoppers survived as long as did an equal number of non-viruliferous individuals. He concluded that the virus itself is neither beneficial nor injurious to adult aster leafhoppers.

A report from Japan (Yoshii and Kiso, 1957), indicates that

in several respects the virus causing dwarf disease of orange alters the metabolism of infected orange leaves and the metabolism of the plant hopper vector, *Geisha distinctissima* Wal., in a similar manner. For example, oxygen consumption and total phosphorus were reduced in both host plant and vector. The publication does not indicate whether or not these metabolic disturbances adversely affected the infective insects in a way that was reflected in reduced longevity, reproduction or activity.

Recently we have been able to demonstrate that the most important stone fruit virus in western North America, Western X-disease virus, causes the premature death of at least one of its leafhopper vectors.

Colladonus montanus (Van Duzee) had proved to be an exceedingly inefficient vector of the virus from peach to peach. However, after the discovery that celery is also a susceptible plant host of the virus (Jensen, 1956), *C. montanus* was retested using celery as the virus source. From these experiments it was determined that *C. montanus* readily acquires the virus from celery. Groups of leafhoppers, fed alternately on a series of healthy peach and celery plants, transmitted virus to 57 of 213 celery plants but to only four of 238 peach trees (Jensen, 1957). Because of the superiority of celery over peach as both a virus source and a test plant and because *C. montanus* lives well on celery but dies rapidly on peach, experiments comparing the longevity of viruliferous and non-viruliferous leafhoppers were carried out on celery. Longevity was measured from the first day on test plants which was after completion of the average latent period of the virus in the vector.

The experiments, reported elsewhere (Jensen, 1958; 1959), show that Western X-disease virus itself causes the premature death of its insect vector. The leafhoppers which did not transmit virus survived on the test plants approximately twice as long as did the transmitters. The increased mortality was not due to altered plant nutrition, because in many of the tests all insects, both transmitters and non-transmitters, fed together on the same virus source plants. The single variable was whether or not a given individual happened to acquire virus from the diseased plant upon which all had fed.

Moreover, an alternative explanation cannot be found in inherent differences between individual leafhoppers. The percentage of insects proving to be infective was usually directly proportional to the access time on the inoculum plant. Thus, in one experiment

insects from the same stock colony were caged on a diseased plant and removed from the plant as three different groups each with a different acquisition feeding time. Of those removed after three days, 27 per cent transmitted virus. After seven days, 70 per cent transmitted and after 16 days 90 per cent transmitted virus. In each group, longevity was greatest among the non-transmitters.

Multiplication of Virus in Insect Vectors

Multiplication of persistent viruses in their aphid vectors has not yet been demonstrated conclusively. Day (1955) reported experiments which suggested to him that potato leaf roll virus multiplies in the aphid *Myzus persicae*. However, Harrison (1958) found that infectivity and retention of this virus by *M. persicae* increased with feeding time on a virus source and that aphids gradually lost their virus on immune hosts. He concluded that the virus does not multiply in the aphid.

It has now been well-established that four plant viruses do multiply in their leafhopper vectors as well as in their plant hosts. These are the viruses of rice stunt, clover club-leaf, aster yellows and wound tumor.

Fukushi (1939) demonstrated that rice stunt virus is transmitted transovarially by its vector *Nephotettix apicalis* Motschulsky var. *cincticeps* Uhler. Starting with a single infective female, the experiment was carried through six leafhopper generations over a period of 374 days. At the end of the experiment there was no evidence of a decline in the number of insects per generation becoming infective nor in the percentage of plants infected.

Black (1950) carried out an experiment, similar to that of Fukushi, with clover club-leaf virus and its vector *Agalliopsis novella* (Say). Starting with a single viruliferous female, Black maintained the insects for five years and through 21 generations on alfalfa which is immune to the virus. At the end of this period there was no reduction in virus infectivity in the insects. If there was no multiplication in the insects the virus would have to retain its infectivity at a dilution conservatively estimated to exceed $1:2.8\times10^{25}$. This is far beyond the dilution tolerance of the virus and means that the virus multiplies in the vector.

Occasional transmission of plant virus through the egg of the insect vector has also been reported by Black (1953) for wound-tumor virus and potato yellow dwarf virus in their respective vectors, *Agalliopsis novella* and *Agallia constricta* Van Duzee. Also,

Grylls (1954) reported that rugose leaf curl virus is transmitted through the egg of its leafhopper vector, *Austroagallia torrida* Evans. It is not yet known whether these viruses can persist in their vectors generation after generation, as has been demonstrated for the viruses causing rice stunt and clover club leaf, without being replenished by feeding on a diseased plant.

That aster yellows virus (Black, 1941; Maramorosch, 1952) and wound tumor virus (Black & Brakke, 1952) multiply in their respective leafhopper vectors has been shown by serial passage of the viruses through their vectors. Diluted virus was injected mechanically into the bodies of the vectors. Later, virus was recovered from the same insects, diluted, and injected into fresh leafhoppers. Ten such serial passages were made with aster yellows virus and seven with wound tumor virus, yet the concentration of virus in the insects attained as high a level in the last passages as in the first. In the absence of multiplication one would have to postulate a dilutions of 10^{-40} for aster yellows virus and 10^{-18} for wound tumor virus.

It is probable that among the many other leafhopper transmitted viruses, especially those having long incubation periods in the vector, will be found additional plant viruses which also multiply in insects. However, it should not be assumed that all leafhopper vectors are also virus hosts. Freitag (1936) and Bennett and Wallace (1938) have presented strong evidence that curly top virus of sugar beets does not multiply in the beet leafhopper, *Circulifer tenellus* (Baker). It should be added, however, that this virus has a very short (approximately 24 hours) incubation period in the vector.

Virus Origin

After tobacco mosaic virus was purified and shown to be a crystalline protein (Stanley, 1935), viruses were considered by some to be unrelated to living organisms. It was suggested that plant viruses originated first from plant cell components and secondarily developed the broad spectrum of specialization which ranges from little or no dependence upon insect vectors, such as in the case with tobacco mosaic virus, up to the leafhopper transmitted viruses, most of which require insects for their dissemination.

In opposition to this idea, is the organismal theory of virus origin proposed by Green (1935) and supported by Laidlaw

(1938), Andrewes (1952) and others. According to this view viruses originated by retrograde evolution from parasitic microorganisms possibly akin to protozoa and bacteria. The fact that we now have several viruses which multiply in animals (insects) as well as in plants has brought into greater prominence the organismal theory of virus origin, and has resulted in its extension (Maramorosch. 1954) to suggest that plant viruses were originally arthropod viruses.

Viruses had been observed to cause disease symptoms in the plant hosts, but not in the insect vectors. Until plant viruses were demonstrated to multiply in the insect vector, their association with insects had been considered somewhat fortuitous. However, with the knowledge that some insects are hosts and not merely vectors of these viruses the way was open to new interpretations as to virus origin.

Among the widely held generalizations in biology is one stating that those parasite relationships which are characterized by severe damage to the host are of relatively recent origin whereas those in which the parasite lives at the expense of the host but causes the latter little or no damage are of much greater antiquity. Thus plant hosts, such as those of aster yellows virus, which suffer extreme damage, would be considered recently acquired hosts. The leafhoppers in which this virus also multiplies without apparent harm would be considered primitive hosts. Andrewes (1957) has reviewed this subject extensively and suggests that arthropods may have been the original hosts not only of the insect viruses, but also of viruses commonly associated with plants and with vertebrates. Insects play a critical role in all three of these general groups of viruses. Originally viruses may have had insects as their only hosts. Later the viruses may have made use of vertebrates and plants to get from one insect to another. Lest we become too carried away by this argument, however, it should be pointed out that in the host range of some plant viruses and some vertebrate viruses there are species which are as symptomless as are the vectors which transmit the viruses. Nonetheless, this does not invalidate the theory. It merely means that such viruses may have been associated with the symptomless hosts much longer than with those still suffering damage. Andrewes (1957) points out that epidemics of yellow fever disease occur in South American monkeys but not in African monkeys. The virus appears to be

harmless to African monkeys and for this reason it may be inferred that the virus has existed in Africa much longer than in the New World.

Similar examples occur among plant viruses. The virus causing Pierce's disease in grapes is probably of New World origin because its effect on the native American species of *Vitis* is mild whereas it is lethal to the introduced *Vitis vinifera* Linnaeus, the grape of history, which is considered to be native from southeastern Europe to western India. Also in America is a long list of apparently symptomless host plants of Pierce's disease virus, ranging from grasses to woody shrubs. Moreover, in America are many species and high populations of "sharpshooters," the leafhopper vectors of Pierce's disease virus. This group of leafhoppers is almost without representation in Europe.

The recent discovery of a plant virus which causes harm to its insect vector adds support to the theory of an insect origin of plant viruses. It provides more conclusive evidence that certain plant viruses are also animal viruses. Moreover, it supplies a concrete example of one stage in the postulated evolution of a virus which until now existed only in theory. It may even raise a doubt, however microscopic, regarding the validity of one of our oldest generalizations in virology, namely, that humans and other vertebrates are immune to injury by plant viruses.

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PYRAMIDOBELA ANGELARUM KEIFER ON ORNAMENTAL BUDDLEIA IN THE SAN FRANCISCO BAY AREA

(Lepidoptera: Ethmiidae)

Pyramidobela angelarum was described in 1936[1] from southern California. Specimens had been reared in Los Angeles, Santa Ana, and Santa Paula from various introduced species of *Buddleia*, and Keifer presumed that the moth had moved into the area from a more tropical region. The species was believed to breed continuously throughout the year, larvae having been collected in April, July, and October.

In recent years the species has apparently become established around the San Francisco Bay area, our first record having been an infestation at San Bruno, San Mateo County in May 1949. During the last four years adults have been taken at lights in Berkeley, Alameda County, in October, December, February, and April (Powell, J. R. Powers, G. I. Stage) and in Pleasant Hill, Contra Costa County, in May (P. A. Opler).—A. E. PRITCHARD and J. A. POWELL, *University of California, Berkeley.*

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THE 1958 MIGRATION OF THE PAINTED LADY BUTTERFLY, VANESSA CARDUI (LINNAEUS), IN CALIFORNIA

(Lepidoptera: Nymphalidae)

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The most recent migration of the painted lady butterfly, *Vanessa cardui* (Linnaeus), was particularly notable for its long duration, from November, 1957 through May, 1958. Observations on this migration have yielded rather definite information on several doubtful points and are the subject of this paper.

The previous reports by the present author on the migration of this species (Abbott, 1950, 1951), based on the migrations of 1924, 1926, 1941, 1945, and 1949, determined various points which will be referred to here only incidentally. It became apparent from these studies that the breeding area of this species, in non-migration years, is chiefly, if not entirely, south of the California-Mexico border, probably in both Baja California and Sonora. Comparatively few of the butterflies are found in California in a non-migration year, and these few chiefly in the Colorado Desert. In a migration year the number emerging in these breeding areas is presumably much greater. One result is a very visible diurnal migration, in a generally north-northwest direction, covering southern California and in some years north to the San Francisco Bay region. Yet the final eggs laid in these regions where it is an immigrant fail to result in a permanent occupation of this more northern habitat.

As in the preceding studies, the present report results from a cooperative study; in this case with the added advantage that most of the contributors are professional entomologists. Thanks to the continued interest of R. F. Smith in collecting data for the project, valuable contributions were secured from the following members of the staff of the Department of Entomology and Parasitology, University of California, Berkeley: P. D. Hurd, Jr., E. G. Linsley, J. W. MacSwain, R. F. Smith, W. E. Ferguson, J. A. Powell and from the following members of the Agricultural Extension Service: G. Beards, J. Dibble, R. Emparin, G. L. Smith, J. E. Swift. I am also indebted to R. C. Dickson of the Citrus Experiment Station, University of California, Riverside, and G. D. Peterson, Jr., Farm Adviser for Imperial County, for descriptions of the winter and early spring invasion of the

Colorado Desert, and to C. E. Strickler, Park Supervisor, and D. E. Merkel, State Park Naturalist, for data for the entire season from Anza-Borrego State Park. L. M. Martin of the Los Angeles County Museum has been helpful with both data and criticisms. Credit for individual contributions will be indicated in the text. It should be understood that the author alone is responsible for the conclusions drawn from the data.

The present status of our knowledge of insect migration in general and of Lepidoptera in particular is summarized in two recent papers by Williams (1949, 1957). The word "migration" is defined by Williams (1949) as "a change of location which is determined both in distance and direction by the insect itself, and not a passive distribution of individuals by overpowering forces such as strong winds."

The present year, 1958, has presented a picture of a longer continuing migration than any other in recent years. The season was mild, with early rainfall resulting in extensive desert vegetation. Butterflies of this species emerged very early in their normal breeding areas in northern Mexico in such numbers as to result in migration. Numbers of them had already reached the southern part of Anza-Borrego State Park by November, 1957 (Merkel), and Imperial Valley by late December (Peterson). Peterson wrote: "As near as I could determine from actual flight observations plus population density counts, the butterflies seemed to be migrating generally from the desert areas south and east of Imperial County and toward the north and northwest."

Dickson wrote: "I first noticed the migration of painted lady butterflies about the last week of January or possibly the week before that. About that time I heard that automobiles coming into Holtville from Yuma had the radiators practically clogged by these butterflies. They were moving out of Sonora, flying northwest to west, and more particularly numerous near Carpinteria."

"The painted ladies have laid eggs on suitable host plants (particularly *Cryptantha* and *Malva*) all over the deserts and desert valleys. Large numbers of larvae are now (March 17) feeding on these plants all over the Colorado Desert so that this area may be a source of a later flight this season."

The emergence of second generation adults from these metamorphosed larvae was recorded in February in Imperial County

by Peterson, who concluded that they joined the general migration which had been proceeding without interruption, and in Borrego State Park by Merkel, who described increasing large swarms somewhat farther north than the November–December emergence, but did not observe the actual migration.

The height of the migration in the valleys of southern California was in late February and early March. Under date of March 17, Dickson wrote: "There has been some flight through Riverside the past three weeks, but greater numbers flew through Beaumont, Redlands, and Colton. Presumably others flew over the Mojave Desert since I hear that some have reached the San Joaquin Valley. I did not see any flight this week either on the desert or in Riverside. This might indicate that the flight is over for this year, or only that the cold weather has slowed emergence of new butterflies in their areas of origin." During this period the "Redlands Facts" reported that "endless swarms" were flying through Redlands.

The "Los Angeles Times" reported on March 5 and 6 that a "great invasion" had occurred in the Los Angeles area March 2–4. Particular mention was made of Hollywood, the Hollywood hills, and the San Fernando and San Gabriel Valleys. The author observed that they were still common at San Fernando, although not in "millions," on March 18 and 19. Many of them were stopping to feed on wild radish flowers in vacant lots, before continuing their flight to the north-northwest.

The western edge of this February–March migration was recorded by the author at Redondo Beach. Individual *V. cardui* were observed on garden flowers on January 4, 16, February 5, 19, 26, 27, March 9, 29; actual migrating butterflies were observed February 21, daily March 1–6, 11, 16. The migration was steady March 2–4, one or two per minute, the same days as the maximum in Los Angeles.

After an interval in late March and early April, which was marked by cold and rainy weather, a heavy migration wave occurred in the middle of April in the San Joaquin and Salinas Valleys. Summarized in brief:

San Joaquin Valley.—Heavy migration throughout valley from south and east of Bakersfield to the region west and north of Tracy. First flight recorded April 8, at height April 10, 11, began to decline April 17, moderate flight April 20, a few stragglers

April 23 (R. F. Smith, Hurd, Linsley, MacSwain, Ferguson). Stragglers to May 9 (R. F. Smith, Swift).

On April 13 they were abundant near Mt. Diablo (R. F. Smith). On April 20 there was a heavy flight in the Walnut Creek region (R. F. Smith, Swift).

Salinas Valley, April 17.—Migration reported (Dibble, Emparin).

The author made one observation of three migrants at Redondo Beach on April 19, but has no other report of this third generation from the Los Angeles area.

Larvae, presumably from eggs laid by these April migrants, were so abundant in the San Joaquin and Salinas Valleys from about April 20 to May 9 that they were found not only on wild plants, but damaging alfalfa, lettuce, and other crops (R. F. Smith, Swift). They were also abundant in clover fields in Glenn County, farther north (reported by R. F. Smith). At Shafter, near the southern end of San Joaquin Valley, the larvae were abundant from about April 10, and in some cases caused enough damage to cotton fields to require control measures (G. L. Smith, Beards).

The above description shows an apparent pattern of a built-up migration through three generations rapidly succeeding each other. Most published descriptions of former spring migrations of this species have assumed that the migrating adults were all of one generation and in general from a common source. This has applied not only to migrations in California and Utah, but also to those in Europe. Campbell (1924) in California and Woodbury *et al.* (1942) in Utah described egg-laying along the way, with the possibility that a new generation from these eggs took part in a later migration the same year. It has, however, seemed more usual that the larvae from these eggs either did not develop to the adult stage, or, because of the smaller numbers, their presence or possible later flight went unnoticed, except in rare instances.

The interpretation of numbers of generations involved is complicated by the apparent great variation in the length of the egg, larva, and pupa stages. L. M. Martin, after checking the literature, wrote me (June 19, 1958): "As far as I can find out, there are no figures on the length of these stages. We know that they vary, for instance, in the egg stage from 7–60 days. The

larval stage varies from 13–41 days and the pupae have been known to stay in that stage for eight months."

The most distinct three generation pattern is found in the records of D. E. Merkel, State Park Naturalist at the Anza-Borrego State Park. As a background, Merkel notes that in the period 1956–57, prior to November 1, 1957, no painted ladies were observed in the park. "If any were present, they were in such small numbers as not to attract attention." This appears to eliminate the Park as part of the breeding area in non-migration years.

As the earliest record of the 1958 migration, large swarms were first noted in November, 1957, in the Mud Hills region in the southern part of the Park. They had apparently emerged farther south, probably in northern Mexico, and had flown north to this secondary breeding area. The subsequent history is as follows: January, 1958, in same Mud Hills region, many pupal casts. February, 1958, at Borrego Campground area, about 25 miles farther north, increasing large swarms of adults. March, 1958. Larvae numerous throughout Borrego Valley, some beginning to pupate. April, 1958. Adults numerous in valley. Empty pupal cases abundant, probably of this species (also noted by Ferguson).

The above summary shows at least three generations. The November generation probably came from last year's eggs in the normal breeding area in northern Mexico, following a long pupal stage during the summer and fall. The second began to emerge in late January, reaching a maximum in February, and the third began to emerge in late March, reaching a maximum in April.

The first and second of these generations were also observed by Peterson in Imperial Valley. He recorded a steady migration from about December 20, lasting six or eight weeks, corresponding to the November and February periods of adult abundance reported by Merkel. Peterson thinks it is probable that two generations of larvae were abundant on desert hosts (mainly *Cryptantha* spp.) during this period, although, because of continuous migration, he could not separate them. "There may have been an extremely small third generation in the cultivated area of Imperial Valley, but this is in doubt." The decrease in numbers could have been caused by most of the second generation adults

migrating before egg laying, or by a drying up of the food-plants of the second generation larvae, or, as Peterson suggests, parasitism of the larvae may slow down the numbers of each successive generation.

The timing suggests that these second generation migrants are those reported as numerous through the San Gorgonio Pass and San Bernardino Valley regions in February and which were numerous in the Los Angeles region in early March. These reached the San Joaquin Valley, laid eggs, and from the eggs came the very abundant migrants observed throughout the valley in the middle of April. (Linsley and MacBride noted that these migrants seemed to be nearly all fresh specimens). Also belonging to this same third generation were those reported from Salinas Valley April 17, Mt. Diablo April 13, and Walnut Creek April 20.

It is not so easy to interpret the observations made in the desert in April, but the time element is again used. The names of the observers are given, the assignment to generations is by the author.

Colorado Desert, 18 miles west of Blythe, April 14–18.—Enormous numbers of hatched and parasitized pupae (eggs laid by second generation). Few adults left (Hurd, Powell). Most of the adults which had emerged must have flown north-northwest (third generation).

Borrego Desert, April 11–18.—Emerged pupae (eggs laid by second generation) abundant. Adults abundant, but not seen to be migrating (third generation) (Ferguson, Merkel).

Eastern Mojave Desert, April 12, near Amboy.—Pupae abundant, not emerged (eggs laid by second generation). Some worn adults, which had probably flown from farther south. A few adults near Topock, Arizona April 14 (Linsley, MacSwain).

Western Mojave Desert, April 12, 13, 14, 19.—Mature larvae abundant (eggs laid by second generation). Some adults migrating (third generation) (Hurd, Powell, Linsley, MacSwain).

These interpretations as to the principal generations involved do not eliminate the probability that some members of each generation flew farther than the ones here described, either before depositing eggs or afterwards. The timing best fits the basic interpretation here given, but there is probability of an overlapping of generations in each locality.

The larvae from eggs laid by the third generation were those

found so abundant in the San Joaquin and Salinas Valleys from about April 20 to May 9 that they were transferring from weeds to vegetables. Larvae found at the same time in Glenn County showed that adults of the third generation had reached there. This appears to show that it was the third generation larvae which were in such numbers as to be considered destructive, although it may be because these reports were from regions which have extensive field crops.

Reports of a fourth generation and on the final extent of the 1958 migration are fragmentary. J. A. and F. C. Powell collected *V. cardui* in Siskiyou and Del Norte Counties on seven scattered dates between June 23 and August 29, while G. Pitman found them on September 12, also in Siskiyou County. Specimens appeared fresh on June 24, 26, July 9, 18, August 4. This suggests continuation of the migration to the Oregon border and at least a fourth generation.

Based on preceding years of observation, it may be predicted that there will be no increase in resident population of *V. cardui* in 1959 in the regions invaded. The population control is discussed below under parasitism of larvae.

The butterfly *Vanessa cardui* (Linnaeus) received its specific name from the thistle, and is commonly thought to lay its eggs chiefly on thistles. But in California, where thistles are not particularly abundant, other plants appear to be just as acceptable as food plants for the larvae. This year's observations emphasize a number of these, as follows:

Colorado Desert: *Cryptantha* spp. (Peterson).
Colorado Desert: *Cryptantha, Malva* (Dickson).
Mojave Desert: *Cryptantha, Amsinckia, Phacelia* (Hurd, Powell).
Mojave Desert: *Cryptantha,* lupine, mallow (Linsley, MacSwain).
San Joaquin Valley: *Amsinckia.* Alfalfa, lettuce, and other crops (Swift).
San Joaquin Valley: *Malva, Amsinckia,* sunflowers, weeds, cotton (G. L. Smith, Beards).
Glenn County: Yellow star thistle, *Amsinckia,* dock (reported by R. F. Smith).
Salinas Valley: Nettle, lettuce (reported by R. F. Smith).

This shows that a considerable variety of wild plants are utilized and that in a year of special abundance, cultivated crops may be attacked. This favors large succeeding generations in the same year and continuation of migration.

The causes of a population increase resulting in a heavy

migration have already been enumerated to include a mild winter, a large amount of rainfall, and consequent abundant desert vegetation. In addition, in 1958, an unusually long favorable season has resulted in a build-up of population through at least three generations in one spring, with migration occurring in all of them. Yet it is almost an axiom that such a migration does not result in colonizing new areas or in increasing the permanent population in the areas reached. Possible checks are too rigorous a winter climate, effective toward the north, drying up of the food plants on which eggs are laid, effective toward the south and in arid climates, and control by parasitic attack. This last point will be discussed further.

Elton (1927), after extensive studies of population control, concluded that the most effective end of an outbreak or plague, whether resulting in a migration or not, is caused by some form of parasitic attack.

Schrader (1928) emphasized that *Vanassa cardui* (L.) is subject to the attacks of "a considerable number of parasitic wasps and flies." Essig (1926) in his section on Tachinid flies, names three species, *Zenillia blanda*, *Frontina archippivora*, and *Chaetogaedia monticola*, which have been reared from larvae of *V. cardui*. This statement in no way limits the number of possible parasites.

The prevalence of parasitism is shown by several of this year's reports, as follows.

"Adult emergence within (Imperial County) was much less than would appear to be indicated by the larval populations present on the desert. This was undoubtedly due to the high rate of parasitization by both insects (Tachinidae) and entomophthorous fungi." (Letter from G. D. Peterson, Jr., May 19, 1958.)

"At Topock, Arizona, on April 14 we observed relatively few butterflies but enormous numbers of Chalcid wasps which had apparently emerged in that area. These wasps were congregated around a creosote bush and several thousand were taken in a single swing of the net." (Letter from J. W. MacSwain, May 23, 1958.) The possibility is suggested that many of these may have emerged from *V. cardui* larvae and may account for the small number of adults observed.

". . . enormous numbers of hatched and parasitized pupae present at the 18 miles west of Blythe locality in late April. The

few adults present could be stragglers, late emergences, etc., which had not gone farther north yet." (Letter from J. A. Powell, May 19, 1958.)

The fact that the direction of flight of migrating *V. cardui* through California is mostly toward the north-northwest and directly against the prevailing wind has been generally observed in all the migrations on record. In the 1958 reports, this was emphasized by Dickson and Peterson in the Colorado Desert, by Dickson in describing the course taken through southern California, by Linsley, MacSwain, and Ferguson in the San Joaquin Valley, and by R. F. Smith and Swift in the Walnut Creek region. The most important variant was in the San Joaquin Valley on April 20, when the majority were flying northwest near Merced, mostly west Merced to Tracy, and mostly north west of Tracy (Linsley and MacSwain). It was not reported whether there was any difference in the wind direction between the regions just enumerated.

The author made a few observations on the direction of flight of 1958 migrants at Redondo Beach, about 1000 feet back from the ocean front. As the migrants came over singly, it was possible to follow the flight of individual butterflies. Variable winds are normal at Redondo Beach. The beach faces the west and the fair weather winds vary from northwest to southwest and on any day constantly fluctuate. The early morning winds are usually northeast, and on days of desert winds there may be northeast gusts all day. Because of the very small numbers of butterflies recorded, any conclusions as to the effect of direction of wind on direction of flight are very tentative. There was an observed tendency of butterflies to fly into the northeast wind in the morning (observed on five mornings at varying times from 7:45 to 11:20), and for the flight to be chiefly northwest, but varying slightly toward the north, during the afternoon. The limited observations support the former observations that flight, whether individual or mass, is usually straight into the wind, with little individual variation (Abbott, 1951).

A survey of collected information on the migration of *Vanessa cardui* (L.) in North America points to its classification as a unidirectional flight with no return (Williams, 1930, 1938, Abbott, 1951). Study of it in California has the special advantage that the compass direction of flight is clearly seen, the same prevailing direction occurs in every migration year, and the numbers in-

volved are great enough to insure the accuracy of these two statements.

The fact that years of general migration occur at intervals, four years more or less, supports the theory that migration occurs only when a population has been built up to what Chapman (1939) calls "outbreak proportions." Chapman describes this as resulting from a relaxation of environmental resistance. This might occur and take effect all in one generation, or it could be cumulative in result, reaching outbreak proportions after a series of generations. The occurrence of migrations at irregular intervals of years favors the cumulative interpretation, whereas a great migration in a year which is particularly favorable from an environmental standpoint indicates that it might occur in one generation.

Observations on the 1958 migration suggest another kind of cumulative result, namely, pressure of population and resulting migration continued through three generations, all of them developed under exceptionally favorable conditions. It may also be emphasized that larvae of the third generation were so numerous as to be destructive of cultivated crops.

In the reports of former years (Abbott, 1950, 1951) it was noted that the migration was in a series of waves of abundance, particularly in 1926 and 1941. It was interpreted that the flight was periodically slowed down by unfavorable weather. No data were available to show a succession of generations. Both factors were apparently involved in the 1958 season. The weather might affect metamorphosis of larvae as well as flight of adults.

Migration is only one of the results of an excessive increase in population, and why it affects only certain species has not been determined. It may be mentioned that Williams, after collecting all available information on migration of Lepidoptera, concludes that there are many more migratory species than the most abundant and conspicuous ones which are well known. He states (Williams, 1949): "We have evidence today of migration in two or three hundred species of butterflies from almost all parts of the world. In about fifty of these there is a considerable weight of evidence which makes it almost impossible to accept any other explanation." In another reference (Williams, 1957) he states that 20 or 30 migrant species are known from the United States.

Summary

(1) The migration of the painted lady butterfly, *Vanessa*

cardui (L.), in California in the spring of 1958 was exceptional in its duration from November, 1957 to May, 1958, as well as in the great numbers of individual butterflies involved.

(2) The north-northwestward distribution during the period was gradual and was correlated with the development of three generations. The first generation invaded the Colorado Desert from northern Mexico from November, 1957 to January, 1958. The second generation emerged on the Colorado Desert from eggs laid by the first generation and flew north in February and early March through the San Bernardino Valley and the Los Angeles area to the Mojave Desert and the San Joaquin Valley. The third generation, emerging in the two last named regions, but chiefly in the San Joaquin Valley, resulted in a great flight through the San Joaquin and Salinas Valleys in the middle of April. The large number of larvae resulting from this third wave of the flight attacked various field crops.

(3) The continuance of a migatory flight through successive generations is favored by the fact that several widely distributed food plants serve as food for the larvae. This applies to both wild and cultivated plants.

(4) Extensive parasitism during the larval and pupal stages was noted by several observers in both the Colorado and Mojave Deserts. This furnished evidence toward the theory of Elton (1927) that parasitic attack is the most important control of an insect outbreak, whether or not accompanied by migration.

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TWO NEW RECORDS FOR THE CONE BEETLE GENUS CONOPHTHORUS HOPKINS IN CALIFORNIA

(Coleoptera: Scolytidae)

During the summer of 1956, a collection of cones of the western white pine, *Pinus monticola* Douglas was made in the Lassen Volcanic National Park area, Lassen County. Two specimens of *Conophthorus monticolae* Hopkins were reared from one of the cones. This species of cone beetle has been previously known only from the cones of the western white pine in Idaho, Washington and Canada (Keen 1958[1]). During the same summer and following summers, collections of cones of the lodgepole pine, *Pinus contorta* var. *latifolia* S. Wats were made from several locations in the Sierra Nevada mountains. In Calaveras and Tuolumne Counties, the cones of this pine were found to be heavily infested with *Conophthorus contortae* Hopkins. Until now, this species has only been recorded from the cones of the shore pine, *Pinus contorta* var. *contorta* S. Wats near Newport, Oregon (Keen 1958). The author is indebted to Dr. S. L. Wood of Brigham Young University in Provo, Utah for the identification of these beetles.—HERBERT RUCKES, JR., *University of California, Berkeley.*[2]

1 Keen, F. P., 1958—Cone and Seed Insects of western forest trees. U.S.D.A. Technical Bulletin No. 1169, pp. 48 & 55.

2 Studies of the cone and seed insect problems of the pines in California made possible by a grant from the Gilbert M. Walker Fund.

NOTES ON MORIUS OCCIDENS CASEY WITH A DESCRIPTION OF THE MALE

(Coleoptera: Pselaphidae)

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University of California, Davis

On the basis of a unique female, broken into many parts, Thomas L. Casey described *Morius occidens* in 1893. Casey's description is to be found in Bowman's Pselaphidae of North America and the genus is keyed into the North American pselaphid fauna by Park (1953). The male has not previously been described.

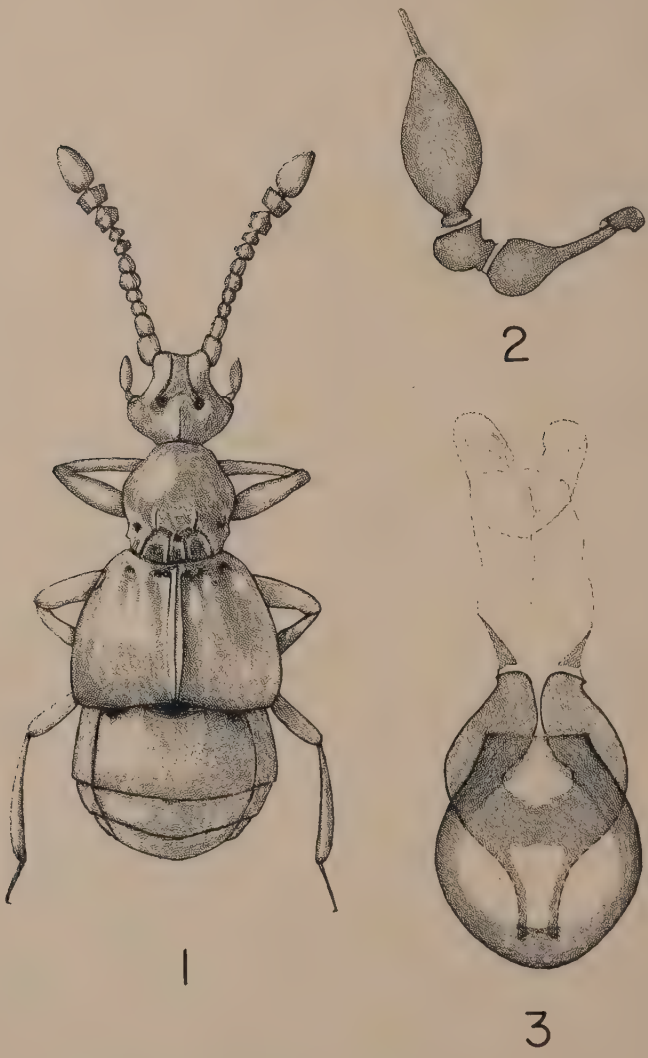
The genera *Morius* and *Rhinoscepsis* are the only North American representatives of the subtribe Rhinoscepsina, tribe Euplectini. *Morius* was previously known only from the type collected in Santa Cruz County, California.

What appears to be one species of *Morius* has been recovered at a low frequency from leaf mold in the Coast Range from Monterey to Mendocino Counties in California. The number of specimens in the series now available for study is insufficient to determine the nature of variation, mainly color and degree of pubescence. The male is associated with Casey's female because (1) it is the predominant form recovered in Santa Cruz County, (2) it is of the proper size and color, and (3) it agrees with the type except for the male sexual characters. (Comparison with the type, which I have not seen, was made by Gordon A. Marsh.)

Casey's original description was good, and only a few characters, mainly of the mouth parts of the female, and those pertaining to the male are described here.

MORIUS OCCIDENS Casey

Additions to description of female. Head as in Casey's description but with weak median carina extending from neck to about the vertexal foveae. Labrum straight across the front, rounded at lateral margins; 2 cone-shaped structures occur medially on lower front margin and 5 or 6 in a row behind the first 2; 4 macrosetae arise laterally, 1 on the dorsal surface and 3 ventrally. Mandibles heavy, 6 teeth on each inner ramus; 1 lamellate seta occurs midway on the dorsal surface along with a few smaller setae. Maxillary palpus with segment I small, 1/3 length of II; II thin for basal 1/2 and swollen at distal 1/2; III slightly more than 1 3 length of II and equally as wide; IV 3 times as long as III and noticably wider, terminated by a long, thin palpal cone almost 1/2 as long as segment IV; 2 specialized setae occur midway on outer surface. Abdomen of 5 visible tergites and 6 visible sternites. Tergite I with fovea formed by 2 apodemes at each



EXPLANATION OF FIGURES

Morius occidens: Fig. 1, adult male, dorsal aspect; Fig. 2, maxillary palpus; Fig. 3, aedeagus, dorsal aspect.

anterio-lateral margin and a large pubescent excavation occupying the median 1/3; II with a much smaller depression at the anterior margin; other tergites simple; sternite I entire behind coxal lines although this condition is obscured by pubescence on point-mounted specimens; II 3 times as long as I with a deep, pubescent, transverse sulcus at the front margin. Mesosternum with 2 carinae and 3 anterior pubescent foveae; mesocoxae narrowly separated, the coxal cavities confluent but nearly closed by processes of the meso- and metasterna; a large pubescent fovea occurs laterad and one posterior to each coxa; metacoxae contiguous.

Male.—As in the female with the exception of the abdominal tergites. Brachypterous males have been noted and fully winged populations may eventually be found. Six sternites are readily visible, and a seventh, a minute penal plate strongly attached to a genital segment and usually removed with the aedeagus during dissection, is sclerotized distally and may at times be visible externally. A small, semi-triangular projection occurs at the middle of the posterior margin of the third visible sternite. Male aedeagus 0.23 mm. long × 0.15 mm. wide; dorsal surface of capsule membranous, ventral surface mostly so, depending to some extent on the age of the individual; two parameres ventrally, extending to rear of capsule and bridged by wide connection at about 1/2 the length of the aedeagus; a membranous tube, apically bifid, is weakly sclerotized near the apex of each paramere and again at the terminal dichotomy; numerous small pores are present along the apical margin of the parameres and a number of fine setae occur along their lateral margins.

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FOURTH ANNUAL INSECT PHOTOGRAPHIC SALON

The Pacific Branch of the Entomological Society of America announces the fourth annual insect photographic salon to be held in conjunction with its meeting in Sacramento, June 23–25, 1959. Photographs will be judged in three categories: monochrome, color transparency, and color transparency sequence. Deadline for all entries is June 16, 1959. Entry blanks may be obtained from Dr. E. S. Ross, California Academy of Sciences, Golden Gate Park, San Francisco 18, California.

A FEW ODONATA FROM YOSEMITE

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A small collection of dragonflies taken in Yosemite National Park (Tuolumne County, California) and deposited in the University of Michigan Museum of Zoology has been determined by the author. The series was taken July 10–13, 1939, by fifteen children on a "nature hike," under the direction of C. L. Gibson, who gave the specimens to the Museum. The locales represented are Miguel Meadows and Sand Pit Lake in northwestern Yosemite, about two miles southeast of Lake Eleanor at an elevation of 5200 feet. According to Chief Park Ranger Elmer Fladmark *(in litt.*, December 9, 1958) there is no "Sand Pit" Lake at Yosemite and the excavation currently known as Gravel Lake may have had the former name at one time.

In the only collective report on California Odonata to date, Kennedy (1917) listed ten species as occurring in Yosemite:

Lestes dryas Kirby, *Enallagma cyathigerum* (Charpentier), *Amphiagrion abbreviatum* (Selys), *Aeshna interrupta nevadensis* Walker, *Cordulia shurteffi* Scudder, *Libellula pulchella* Drury, *Libellula quadrimaculata* Linnaeus, *Sympetrum semicinctum* (Say), *Leucorrhinia glacialis* Hagen, *Leucorrhinia hudsonica* (Selys).

The following list of fifteen species, none of which constitutes a new state record, includes eleven (indicated by an asterisk) reported from Yosemite for the first time (Sand Pit Lake and Miguel Meadows are abbreviated as SPL and MM respectively):

Lestes dryas Kirby, 5♂♂, 9♀♀, SPL and MM; *Enallagma cyathigerum* (Charpentier), 1♂, SPL; *Ischnura perparva* Selys*, 3♂♂, 2♀♀, SPL and MM; *Anax junius* (Drury)*, 2♂♂, SPL; *Aeshna palmata* Hagen*, 1♂, MM; *Aeshna multicolor* Hagen*, 1♂, SPL; *Libellula pulchella* Drury, 10♂♂, 1♀, SPL and MM; *Libellula quadrimaculata* Linnaeus, 12♂♂, MM; *Libellula saturata* Uhler*, 11♂♂, 1♀, SPL; *Sympetrum corruptum* (Hagen)*, 1♀, SPL; *Sympetrum madidum* (Hagen)*, 2♂♂, 1♀, SPL and MM; *Sympetrum occidentale californicum* Walker*, 1♀, MM; *Sympetrum pallipes* (Hagen)*, 1♂, 2♀♀, SPL and MM; *Leucorrhinia intacta* (Hagen)*, 1♂, 1♀, MM; *Tramea lacerata* Hagen*, 3♂♂, SPL.

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THE JAPYGIDAE OF NORTH AMERICA 1— PROVALLJAPYGINAE AND NANOJAPYX

Leslie M. Smith

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The subfamily Evalljapygинae is characterized by the five pectinate laminae of the lacinia and the bilateral asymmetry of the forceps, as well as other characters. Silvestri (1949) studied three specimens from the state of São Paulo, Brazil and noted that they possessed a falciform distal lamina on the lacinia and nearly bilaterally symmetrical forceps. He named this insect *Provalljapyx lanei* new genus and new species and placed it in the subfamily Evalljapyginae although it did not fit in the two characters mentioned. Paclt (1957) placed Silvestri's genus *Provalljapyx* as a synonym of *Evalljapyx* but, as indicated below, this is not justifiable.

In my collection are 63 specimens representing five species which I assign to the new genus *Nanojapyx*. This genus from California shows affiliation to Silvestri's genus *Provalljapyx* from Brazil. Neither of these genera can be placed logically in the subfamily Evalljapyginae. In my opinion they represent an evolutionary group between the Projapygidae and the Evalljapyginae, and I therefore place them in the new subfamily, Provalljapyginae. All of the Projapygidae known from the New World have plumose body setae and bilaterally symmetrical anal cerci which do not show sexual dimorphism. We may assume that the Projapygidae arose from a primitive campodeid by the shortening and thickening of the anal cerci, and later by the addition of stout spines mesad on the cerci as a defensive mechanism for protection against attack from the rear.

A further step in the evolution is represented by the Provalljapyginae wherein the anal cerci are modified into unsegmented forceps which are symmetrical and do not show sexual dimorphism. The final evolutionary step is exhibited by the Evalljapyginae wherein in the left forcep is different than the right forcep and the forceps of the male are different from those of the female. This line of evolution is also supported by anatomical features other than the forceps.

Provalljapyginae, new subfamily

Similar to the Evalljapginae except: antennae with 20 to 23 segments, distal lamina of lacinia falciform, styli each with a

single seta, tergite VII slightly lobed or bilobed, pleura VII not heavily sclerotized or projected to the rear, forceps approximately similar and without sexual dimorphism, length of body 2 to 4 mm.

Inasmuch as this subfamily is now known from eastern South America and western North America, it seems probable that a rich fauna exists in this group. They have undoubtedly been overlooked by earlier collectors because of their small size and, if seen, they were probably mistaken as nymphal stages of larger species.

Key to the Genera

1. Stylus with a single seta, distal lamina of lacinia falciform, forceps similar (Provalljapyginae) 2
– Stylus with two setate, distal lamina of lacinia pectinate, forceps not bilaterally symmetrical (Evalljapyginae) 3
2. Two large median teeth on each forcep, no other teeth or denticles, posterior seta on pleuron plumose, segment X tergite setae 4 + 1 + 4..... *Provalljapyx*
– Four or more similar teeth on each forcep, posterior seta on pleuron simple, segment X tergite plumose setae 3 + 3..... *Nanojapyx*
3. Setose frontal sinus ..... *Ctenjapyx*
– Without setose frontal sinus ..... *Evalljapyx*

Nanojapyx L. Smith, new genus

Type species: *Nanojapyx pagesi* L. Smith, new species.

Head.—Antenna with 22 ± 1 segments; vertex covered with a number of M[1] and a lesser number of m; distal half of antenna with segments showing two fairly regular rows of m, *a* a little more to the base than to the extremity of the segment, longer than m on the same segment; apical lamina of lacinia falciform, shorter than the other four, pectinate laminae. *Thorax.*—Pronotum 6 + 6 M, meso- and metanotum 7 to 9 + 7 to 9 M; legs, femora dorsal apex with two subequal small usually plumose setae and one simple seta in a line; tarsus with two ventral rows of spine-like setae, two or three setae per row. *Abdomen.*—Tergites with four to five irregular transverse rows of M, and fewer m, M with 6 ± 2 pinnulae; sternites with five irregular transverse rows of M and fewer m, M with 3 ± 2 pinnulae; tergite X with 3 + 3 plumose M between the carinae and a variable number of m; lateral subcoxal organs broad with about four to seven plumose sensory setae each, in a single row, and two or three irregular rows of distinct glandular setae; styli on segments I–VII, each with one mesad seta, approximately one-third as long as the stylus; abdominal pleura; anterior pleurite with two large setae, with the anterior one plumose;

1 Abbreviations: M — macrosetae, plumose; m — sub-macrosetae, usually simple but occasionally plumose, *a* — dorsal sense-seta on the fourth antennal segment; L 1, L 2, L 3, — first, second, and third pair of legs; A, B, C, D — anterior, second, third, and posterior rows of M on the abdominal sclerites; I-X — abdominal segments.

pleuron with three large setae, posterior one simple; forceps apparently symmetrical, differing only in number of teeth, teeth usually sharp pointed, not rounded denticles; all setae on forceps simple, except one or two basal; no sexual dimorphism in forceps.

This genus is close to the genus *Provalljapyx* but can be distinguished from it by the presence of four or more teeth on each forcep.

Nanojapyx pagesi L. Smith, new species

Female.—Head: antenna with 22 segments; segments 13 to 22 with all setae of same size, arranged in two transverse rows, about 16 setae in distal circle, and about 20 setae in basal cricle; segment IV circled with eight to ten larger setae anterior to *a*; labrum with 7 + 7 simple setae of various sizes; mandible with three fused teeth and a fourth, distinct, less heavily sclerotized, pointed tooth; first tooth (ventral) of mandible largest and recurved at tip; galea of maxilla with sclerotized thumb at apex of anterior lobe with five spatulate projections at tip of thumb; palpus with ten simple setae; lacinia heavily sclerotized, arcuate, lamina 1 a rod, shorter than lamina 2; laminae 2 to 5, typical combs; labium with numerous simple setae; labial palpi short, conical, with two long and one short simple setae; dorsum of head with about 24 + 24 setae, mostly all plumose. *Thorax.*—Pronotum with 6 + 6 M and 5 + 4 m; mesonotum, prescutum with 1 + 1 M and 1 + 1 m; scutum with 7 + 8 M and 7 + 7 m; metanotum with 8 + 9 M; legs short, setae at dorsal apex of femur, numbers 1 and 2 plumose, number 3 simple, number 3 longer than number 1, number 2 shortest; large ventral setae on tarsus in two rows of two setae each, tarsal claws simple sub-equal. *Abdomen.*—Tergite I: prescutum with 1 + 1 M and 1 + 1 m, scutum with 6 + 6 M and 6 + 6 m; sternite I—prescutum with 4 + 5 M, and no m, scutum A = 4 + 4 M, B = 2+ 2 M and 2 + 2 m, C = 4 + 4 M, D = 9 + 9M; lateral subcoxal organs with 7 + 7 M and numerous glandular setae arranged in two irregular rows; stylus simple, conical with slightly bulging base, one simple curved seta; tergite II, A = 4 + 4 M, B = 2 + 2 M, C = 2 M and 3 + 3 m alternating in row with M; segments III to VII inclusive similar to segment 2; six ventral setae associated with stylus VII, as illustrated, setae 1, 3, and 5 with 3 or 4 pinnulae, setae 2 and 4 present. Segment VIII width 0.16 mm, length 0.18 mm; tergite, A = 4 + 4 M and 1 + 1 m, B = 2 + 2 M and 1+ 1 m, C = 3 + 3 M and 3 + 3 m alternating in row with M; sternite, A = 3 + 3 M and 1 + 1 m, B = 3 + 3 M and 1 + 1 m, C = 3 + 3 M and 3 + 3 m; spermatheca between B and C, bulbous with a long anterior spike; genital opening with many simple setae, no palps. Segment IX tergite, 3 + 3 M and 3 + 3 m alternating; sternite with 3 + 3 M and 3 + 3 m; segment X, width 0.14 mm, length 0.20 mm; tergite, (between crenulae) A = 2 + 2 M, B = 1 + 1 M, C = 3 + 3 M of which the four mesad setae are simple, about six m scattered over the tergite; sternite A = 3 + 3 M followed by a row 2 + 2 m, B = 2 + 2 M and 1 + 1 m, C = 1 + 1 M, D = 3 + 3 M and 2 + 2 m; acropygidium distinct, rounded, edge crenulate; carinae distinct; forceps short and broad (as illustrated) and strongly bent upward toward

the tips: right forceps with seven sharp, recurved teeth, left forceps with five similar teeth, each forceps with ten large setae of which the outer, basal one is plumose; and nine smaller setae of which four arise near the dental margin; length of forceps 0.14 mm.; length of body, including forceps 2.89 mm.

Male.—Similar to female except no spermathecae; large median internal setose sac opening ventrally on sentum III near the suture between the presentum and sentum, tip of sac extending anteriorly to posterior margin of second urosternite, setae near the mouth of the sac plumose, the rest simple; lateral subcoxal organs with 6 + 6 plumose sensi-setae and numerous hyaline glandular setae almost as long as the sense setae; right forceps with six teeth, left forceps with five teeth; length of body 2.72 mm.

Holotype female and allotype male (California Academy of Sciences) and paratype female and male (University of California, Davis) were collected in leaf mold NEAR OAKLAND, ALAMEDA COUNTY, CALIFORNIA, in January, 1953 by Mr. Robert O. Schuster.

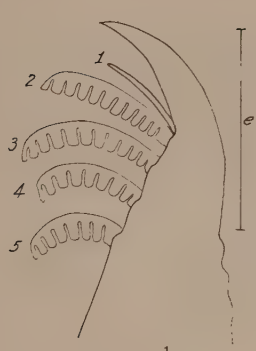
I take pleasure in naming this species after M. L. Pagés of the Laboratoire de Biologie Animale, Université de Dijon, France, in recognition of his fine work in the taxonomy of the Japygidae.

Nanojapyx pricei L. Smith, new species

Female.—Similar to *N. pagesi* L. Smith except setae at dorsal apex of femora, number 3 equal in length to number 1; setae on labial palpi 4; meso-and metanotum 8 + 8 M; setae number 1 on forceps usually simple or minutely plumose; length of forceps 0.18 mm.; right forceps with seven teeth, left with six teeth; tips of forceps strongly curved inward, as illustrated; lateral subcoxal organs each with six or seven plumose sense setae; ventral setae associated with stylus VII as in *pagesi* but with three pinnulae each; abdominal segment X, width 0.20 mm., length 0.28 mm., length of body, including forceps 3.83 mm.

EXPLANATION OF FIGURES

Fig. 1, lacinia of *Nanojapyx pagesi* L. Smith showing rod-like structure of the first lamina, $e = 0.05$ mm.; fig. 2, male sac in III of *pagesi* dorsal view, $e = 0.05$ mm.; fig. 3, spermathecae of *pagesi* dorsal view, fig. 4, eighteenth antennal segment of *pagesi* female, dorsal view, $e = 0.05$ mm.; fig. 5, apex of femur of *pagesi* dorsal view showing plumose setae 1 and 2, and simple seta number 3; fig. 6, tarsus of 1–2 of *pagesi* ventral view showing two rows of two stout setae each, $e = 0.05$ mm.; fig. 7, fourth antennal segment of *pagesi* female, dorsal view showing dorsal sense seta at a; fig. 8, labial palpus of *pagesi* female, ventral view; fig. 9, pleuron of left side of *pagesi* female showing setal pattern, left = pleurite, right = pleuron; fig. 10, tergite X of *pagesi* female, dorsal view, $e = 0.10$ mm.; fig. 11, right stylus VII and associated setae of *pagesi*, ventral view, $e = 0.05$ mm.; fig. 12, right stylus VII and associated setae of *N. gentilei* L. Smith ventral view, $e = 0.05$ mm.



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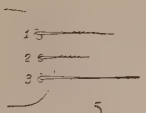

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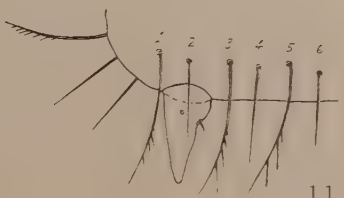

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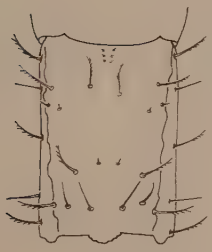

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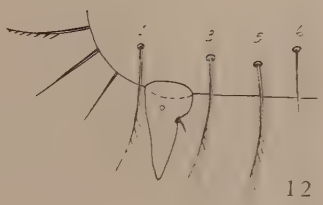

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Male.—Similar to female, except right forcep with six teeth, left with five teeth; male sac with few setae mostly simple, but nine setae show minute pinnulae near the opening of the sac; abdominal segment X, width 0.17 mm, length 0.22 mm; length of body including forceps 3.54 mm.

In addition to the six paratypes, I have examined a series of eight metatype adults from Sharp Park, San Mateo County, California. In some of these the females lack the basal tooth on the right forcep.

Holotype female and allotype male (California Academy of Sciences), and 18 paratypes (California Insect Survey; University of California, Davis; U.S. National Museum) were collected in chaparral leaf mold in the San Bruno Mountains, San Mateo County, California, in January, 1957.

I take pleasure in naming this species after Mr. Douglas W. Price who collected it.

Nanojapyx gentilei L. Smith, new species

Female.—Similar to *N. pagesi* L. Smith except setae at dorsal apex of femora, number 3 longer than number 1, number 2 shortest and not plumose; setae on labial palp 4, setae on maxillary palp 7; meso- and metanotum 7 + 8 M; seta number 1 on forceps minutely plumose; length of forceps 0.12 mm; right forcep with six teeth, left with five teeth, tips of forceps strongly curved inwards; lateral subcoxal organs each with four or five plumose sense setae; ventral setae associated with stylus VII as illustrated with setae number 2 and 4 missing; abdominal segment X, width 0.11 mm, length 0.16 mm; length of body including forceps 2.72 mm.

Male.—Unknown.

Holotype female (California Academy of Sciences), paratype female and juvenile (University of California, Davis) were collected ten to twelve inches deep in sandy soil in a growth of poison oak by L. M. Smith and R. O. Schuster near Trenton, Sonoma County, California, on August 7, 1957.

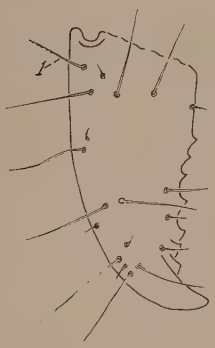
I take pleasure in naming this species for Mr. Adriano Gentile who has been of great assistance to me by translating Silvestri's works on Japygidae from Latin.

Nanojapyx hamoni L. Smith, new species

Female.—Similar to *N. pagesi* L. Smith except setae at dorsal apex of femora, numbers 1 and 2 plumose, with number 3 equal in length to number 1; setae on labial palp 4, setae on maxillary palp 7 + 8; ventral

Explanation of Figures

Forceps of *Nanojapyx* females, dorsal view, reversed left to right, setal pattern of all as shown in fig. 13. All figures at same magnification, e = 0.10 mm. Fig. 13, *pagesi*; fig. 14, *hamoni*, a, right, and b, left forcep; fig. 15, *pricei*; fig. 16, *gentilei*; fig. 17, *coalingae*.



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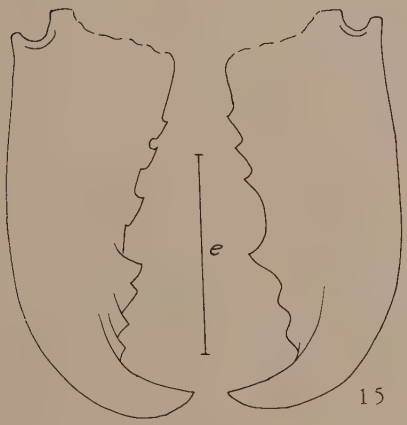

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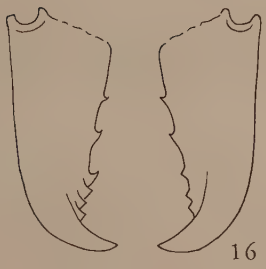

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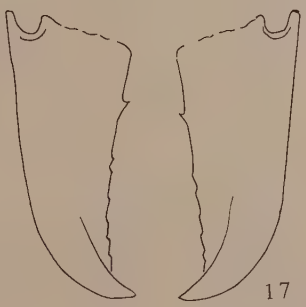

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setae per row on tarsus 3 + 3; meso- and metanotum 7 + 7 M; seta number 1 on forceps minutely plumose: length of forcep 0.14 mm: left forcep with eight teeth with distal tooth almost hidden, right forcep with five teeth, all teeth pyramidal in shape, not recurved; lateral subcoxal organ with 6 + 6 plumose sensory setae; ventral setae associated with stylus VII with setae 2 and 4 present, these become progressively smaller anteriorly, setae 1, 3, and 5 with 4 pinnulae each: segment X, width 0.19 mm, length 0.22 mm; length of body including forceps 3.40 mm.

Male.—Unknown.

Holotype female (California Academy of Sciences) collected in redwood leaf mold near Half Moon Bay, San Mateo County, California on July 21, 1957 by Mr. R. O. Schuster. Three female paratypes were collected in clay-loam soil and humus under Monterey Cypress, by W. H. Lange and R. Schoeppner at Wolf Ranch, San Mateo County, California, April 24, 1958 and are deposited in the collection of the U.S. National Museum, California Insect Survey and the University of California, Davis.

Nanojapyx coalingae L. Smith, new species

Female. Similar to *N. pagesi* L. Smith except antenna with 23 segments: antennal segment 18 with eight setae in the distal whorl: setae at dorsal apex of femora, numbers 1 and 2 plumose with number 1 equal in length to number 3: setae on labial palp 3, setae on maxillary palp 8: meso- and metanotum 7 + 7 M; ventral setae per row on tarsus L 1 = 2 + 2; L 2 and L 3 = 3 + 3; seta number 1 on forceps clearly plumose: tergum X setae between carinae, row A as in *pagesi*, the two pair of m posterior to A strongly developed, row B anterior of middle, C irregular, with one additional pair of m just mesad of the lateral setae, median pair of M posterior, simple, all other M plumose: length of forceps 0.14 mm, right forcep with one distinct sharp pointed recurved tooth and crenulations suggesting reminants of six teeth, left forcep the same: lateral subcoxal organ with 6 + 7 plumose sensory setae: ventral setae associated with stylus VII, seta number 2 present but small, and seta 4 absent: setae 1, 3, and 5 with four or five pinnulae: segment X width 0.14 mm, length 0.20 mm; length of body including forceps 3.06 mm.

Male.—Unknown.

Holotype female (California Academy of Sciences) was collected in juniper leaf mold near Coalinga, Fresno County, California on January 22, 1958, by Mr. H. L. Wilson.

Key to the Species of Nanojapyx L. Smith

1. Antennae with 23 segments ..... *coalingae*
– Antennae with 22 segments 2
2. Three setae per row on tarsus ..... *hamoni*
– Two setae per row on tarsus (fig. 6) 3
3. Three setae on labial palpus (fig. 8) ..... *pagesi*
– Four setae on labial palpus 4

4. Plumose seta at apex of femur shorter than adjacent simple seta (fig. 5) ..... *gentilei*
– Plumose seta at apex of femur same length as adjacent simple seta ..... *pricei*

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RELEASES OF RECENTLY IMPORTED INSECT PARASITES AND PREDATORS IN CALIFORNIA, 1956–57

C. P. Clausen
University of California, Riverside

The following list, reporting the first field releases of certain imported species of parasites and predators by the Department of Biological Control, supplements two preceding reports,[1,2] covering the years 1952–53 and 1954–55. The year of first release is 1957 unless otherwise indicated.

The species listed in the 1952–53 report as *Platynaspis* (?) sp. has since been identified as *Exochomus metallicus* Korschefsky.

Host and Parasites or Predators	*Origin*	*Area or County of Release*
Saissetia oleae (Bern.)		
Coccophagus mexicensis Gir.*	Mexico	So. Calif., Tulare
Mesopeltis atrocyanea Masi	Mexico	San Diego
Metaphycus lichtensiae (How.)	Pakistan	Coastal So. Calif.
Microterys consobrinus Comp.*	Mexico	San Diego
Microterys flavus (How.) (Black scale race)	India	So. Calif.
Aonidiella aurantii (Mask.)		
Aphytis sp. (Burma)	Burma	So. Calif.
Aphytis sp. (India)	India	So. Calif.
Aphytis sp. (Pakistan)	Pakistan	So. Calif.
Chilocorus tristis Fald.[3]	Japan	San Diego San Bernardino
Cybocephalus sp.	India	So. Calif.
Pharoscymnus sp.	India	San Diego

Host and Parasites or Predators	*Origin*	*Area or County of Release*
Physcus sp.	Burma	San Diego Riverside
Telsimia sp.	Burma	So. Calif.
LEPIDOSAPHES BECKII Newm.		
Chilocorus discoideus Crotch*	Kenya	So. Calif.
PARLATORIA OLEAE (Colvée)		
Aphytis sp.	Pakistan	San Joaquin Valley
Archenomus sp.	Pakistan	San Joaquin Valley
Coccophagoides sp.	Pakistan	Fresno Tulare
PLANOCOCCUS CITRI (Risso)		
Nephus sp.	Mexico	Ventura
THERIOAPHIS MACULATA (Buckton)		
Adonia variegata Gze.[4]	India	Riverside Fresno Yolo
Chrysopa carnea Steph.[4]	India	So. Calif. Yolo
Scymus nubilis Muls.[4]	India	Riverside Yolo
Synharmonia conglobata (L.)*	Turkey	San Diego
APHIS SPIRAECOLA Patch		
Aphelinus chaonia Wlkr.*	Hong Kong	Riverside
TETRANYCHIDAE AND ERIOPHYIDAE (various)		
Stethorus sp. "P"	Pakistan	San Diego
Stethorus sp. "D"	India	San Diego Riverside Santa Barbara
PHYTOPHAGOUS SNAILS		
Gonaxis kibweziensis (Smith)*[5]	Agiguan	San Diego

* First releases made in 1956.

1 Pan-Pacific Entom. 31(2) :90-2. 1955.

2 Pan-Pacific Entom. 32(3) :125-7. 1956.

3 Received from Canadian Department of Agriculture.

4 Received from Entomology Research Division, U.S.D.A.

5 Received from Pacific Science Board and Hawaii Board of Agriculture and Forestry.

NOTES ON THE CALIFORNIA SPECIES OF THE GENUS PYLA GROTE

(Lepidoptera: Pyralidoidea)

JERRY A. POWELL

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The black moths of the genus *Pyla* Grote are dayflying phycitids which, in western North America, inhabit boreal regions. Carl Heinrich, in his magnificent monograph of the Phycitinae (1956), divided the genus into two superficial species groups, those with grey forewings and those with shining black-brown wings. Four species are recorded from California, all of which are members of the latter group, the typical *Pyla* of the earlier authors.

During the course of the past few seasons, collecting in the mountains of northern California[1] has produced certain distributional data which seem significant. It has become apparent that *P. sylphiella* Dyar, previously only reported from Washington and British Columbia extends southward and is continuous with the California species, *P. scintillans* (Grote). In addition, a few remarks on variation and a description of the female of *P. nigricula* Heinrich are included in the present paper. Where not otherwise indicated in the data, the collection records are my own.

PYLA SCINTILLANS (Grote)[2]

Nephopteryx scintillans Grote, Papilio, Vol. 1, p. 18, 1881.

Pyla scintillans (Grote), Heinrich, U.S. Nat. Mus., Bull. 207, p. 146, 1956.

Pyla sylphiella Dyar, *Ins. Insc. Menstr.*, Vol. 9, p. 68, 1921; Heinrich, U.S. Nat. Mus., Bull. 207, p. 147, 1956. (New synonymy.)

A shining, dark brown species with usually only faint indications of darker transverse banding on the forewing. Very distinctly marked specimens show dark markings on the forewings as follows: a broad median band which angles slightly outward; a thin subapical, usually somewhat sinuate, band; sometimes an irregular blotch between the bands on the dorsal margin. It may be easily distinguished from *P. fasciella* Barnes and McDunnough and *P. nigricula* Heinrich, which it closely resembles, by its longer palpi (exceed the head by about twice the diameter of the eye as seen from side, fig. 1). Alar expanse 20–26 mm.

1 Field investigations during August, 1957 and July, 1958 carried out with the California Insect Survey, University of California, Berkeley.

2 Complete synonymy has been given by Heinrich (1956).

Heinrich lists the distribution as Sierran, from Mineralking, Tulare County northward to Cisco, Placer County, all at high elevations. It is apparent, however, from the specimens I have examined, that in California the species ranges throughout the Sierras, the north central part of the state, and thence southward along the inner North Coast Ranges for some distance. The species is, in general, an early flier compared to the other California *Pyla*, with almost all collections having been made in July.

Heinrich, in his treatment of the genus, recognized both *P. scintillans* (Grote) and *P. sylphiella* Dyar as valid species even though they are indistinguishable on the basis of external characters. His criteria for separation were: minor differences in the male genitalia, the markedly different female genitalia, and the allopatric distribution of the two species. However, the California specimens of the complex are extremely variable in genitalic characters and include intermediates between his interpretation of *P. scintillans* and *P. sylphiella*. A series from Del Norte County seems to be fairly uniform in representing a southern extension of *P. sylphiella* in both male and female characters. A male from southern Siskiyou County appears to be intermediate in the harpe enlargements, while the aedeagus is of the *P. sylphiella* type. A male from Shasta County, although having the harpe characters of *P. sylphiella*, has one element of the aedeagus with one short thorn, the other with three, a situation typical of *P. scintillans*. The female genitalia in the specimens examined exhibit more variability than was indicated by Heinrich. Typical *P. sylphiella* forms occur in Del Norte and Siskiyou Counties, but not consistently. One interesting variety lacks both the heavily sclerotized deep folds of the lower part of the cup-shaped portion of the ductus bursae characteristic of *P. sylphiella* and the oval, blade-like projections of the cup evident in *P. scintillans*. This variant (fig. 3) has been found in random individuals from Del Norte County and in single specimens from Plumas and Glenn Counties. This may represent an intermediate form. Specimens from the southern Sierras seem more typical of *P. scintillans* in both sexes, but I have not seen any females really typical of either of the *P. scintillans* varieties figured by Heinrich.

In view of the nature of the intergrading characteristics evident in the complex, I regard *Pyla sylphiella* Dyar as a synonym

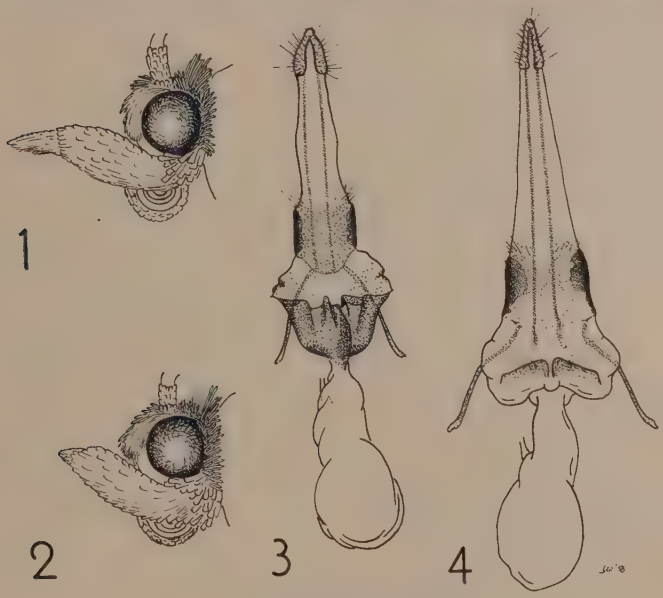
of *P. scintillans* (Grote). *P. scintillans* being a widespread species (central California north to British Columbia).

Material examined: (See map) 1♂, 5 mi. W. Sonora Pass, Tuolumne Co. VII.21.56; 1♀, Sonora Pass, Tuolumne Co. VII.21.56; 1♀, Glen Alpine Cr., El Dorado Co. VII.18.09 (F. X. Williams); 1♀, Mohawk, Plumas Co. VII.8.38 (W. R. Bauer); 1♀, Chester, 6 mi. E., Plumas Co. VII.14.54; 1♂, Hat Creek P. O., Shasta Co. VII.11.56 (J. W. MacSwain); 1♂, "Caslella" [prob. Castella, Shasta Co.] VII.'02 (no collector); 1♂, 1♀, Mt. Shasta City, Siskiyou Co. VII.2.58; 3♂♂, 11♀♀, Little Grayback. N.E. Del Norte Co. VII.9.58; 1♀, 5′ mi. N. Black Butte, Glenn Co. 6200′, VI.19.56.

Pyla nigricula Heinrich

Pyla nigricula Heinrich, U.S. Nat. Mus., Bull. 207, p. 148, 1956.

Superficially *P. nigricula* is very much like *P. scintillans*, from which it differs by the smaller palpi (exceed the head by only about the diameter of the eye as seen from side, fig. 2), and



Explanation of Figures

Fig. 1, Lateral view of head of *Pyla scintillans* (Grote); fig. 2, Lateral view of head of *Pyla nigricula* Heinrich; fig. 3, Female genitalia (variant) of *Pyla scintillans* (Grote); fig. 4, Female genitalia of *Pyla nigricula* Heinrich.

apparently is almost indistinguishable from *P. fasciella*. All three are easily separated by their genital characters. Heinrich described *P. nigricula* from a unique male collected by A. H. Vachell at Verdi, Nevada. I have encountered it at spots to the south of the Lake Tahoe region, but only at elevations above 10,000 feet. Verdi is on the eastern side of the Sierras, and it seems probable that the specimen was collected in the mountains near Verdi to the west.

The male exhibits some variation in wing color, and I have a specimen which differs from the original description as follows: both the antemedial and submarginal dark bands of the forewing clearly indicated, the area between, as well as the margin, with the same bluish overscaling as is present on basal area. Another has just a faint suggestion of the median bluish, otherwise closely resembling the type description. Alar expanse 23–25 mm. (the type is 26 mm.).

The unique type is a male, and the previously unknown female is described at this time.

Head, palpi, other appendages, as in male. *Forewing* black, tinged with bluish overscaling as follows: basal area, median area except for an indistinct center blotch, a thin, distinct submarginal transverse line parallel with margin, marginal area; remaining black bands as follows: antemedial oblique line, irregular blotch at end of cell, two submarginal thin bands on either side of the distinct blue line. (In older specimens the bluish tends to become obscure, giving a less distinctly marked appearance). *Hind wing*, shiny dark brown as in male. Alar expanse 23–24 mm. *Genitalia* as in fig. 4 (three specimens examined), close to *P. fasciella* Barnes and McDunnough but differing by the smaller ovipositor pads (ratio of ovipositor pad length to: posterior apophyses distad of pads to: length of sclerotized band of ninth segment about 1:6:1.5; in *P. fasciella* about 1:4:1) and by minor differences in shape of the sclerotization of the ninth segment and paired plates of ductus bursae.

Neallotype female: SONORA PEAK, TUOLUMNE COUNTY, CALIFORNIA, August 10, 1957 (J. Powell) deposited in the California Insect Survey collection, University of California, Berkeley.

I have not seen *P. fasciella*, but judging from the description given by Heinrich, it is nearly indistinguishable from *P. nigricula* in external characters. Although the genitalia are distinct, the two entities are also geographically isolated (*P. fasciella* is known only from Mt. Shasta in northern California), and perhaps the status of *P. nigricula* should be reëvaluated when more material becomes available, especially from the intervening areas. It seems

a distinct possibility that *P. nigricula* Heinrich represents a genitalic variant.

Material examined: 1 ♀, Ruby Lake, Inyo County [11,250 ft.] VIII.13.57; 1 ♀, near Mono Pass, Inyo County, 12,000′, VIII.11.57 (C. D. MacNeill); 1 ♂, Sonora Pass, Tuolumne County, VII.21.56; 2 ♂ ♂, near Sonora Peak, Tuolumne County, 11,000′, VII.14.57 (C. D. MacNeill); 4 ♀ ♀, Sonora Peak, Tuolumne County, VIII.10.57.

Pyla viridisuffusella Barnes and McDunnough

Pyla viridisuffusella Barnes and McDunnough, Can. Ent., Vol. 49, p. 406, 1917; Heinrich, U.S. Nat. Mus., Bull. 207, p. 149, 1956.

A smaller moth (expanse 17–20 mm.), quite distinct from the

Explanation of Map

Distribution of *Pyla scintillans* (Grote) (closed circles) and *Pyla viridisuffusella* Barnes and McDunnough (open circles) in California according to material examined and localities given by Heinrich (1956).

above mentioned species, with a shining metallic green or bronzy overscaling and usually with rather distinct transverse bands on the forewing. The intensity and quality of the color varies considerably between individuals.

Heinrich gives its distribution as the southern high Sierras, ranging from Mineralking, Tulare County, north to Kennick Meadows, Tuolumne County. The present records extend a little more northward. It was flying quite abundantly in northwest Inyo County in mid-August, along with occasional examples of *P. nigricula* Heinrich and another abundant Phycitine, *Catasia bistriatella* (Hulst), which it resembles on the wing.

Material examined: (See map) 1♂, 2♀♀, Ruby Lake, N.W. Inyo Co. VIII.13.57 (C. D. MacNeill), 7♂♂, 3♀♀, same data (J. Powell); 3♂♂, 2♀♀, nr. Mono Pass, Inyo Co. 12,000′, VIII.(10–15).57 (C. D. MacNeill); 3♂♂, 4♀♀, same data (J. Powell); 1♂, Tuolumne Meadows, Tuolumne Co. "VIII.(1–7)" (no collector); 3♂♂, 1♀, Kennick Meadows, Yosemite Nat'l. Park, alt. 9,250′, VII.28.34 (E. O. Essig); 1♀, nr. Sonora Peak, Tuolumne Co. 11,000′, VII.10.57 (C. D. MacNeill), 2♀♀, same data (J. Powell).

I would like to acknowledge with thanks the help of C. Don MacNeill of the Department of Entomology, California Academy of Sciences, San Francisco, for the loan of specimens and for assistance in the field, and Dr. P. D. Hurd, Jr., of the Department of Entomology, University of California, Berkeley, for reading the manuscript and suggestions.

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OBSERVATIONS ON THE SURVIVAL OF ARHOPALUS PRODUCTUS (LeCONTE) LARVAE IN DOUGLAS-FIR LUMBER

(Coleoptera: Cerambycidae)

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Larvae of the roundheaded borer, *Arhopalus productus* (LeConte), often are found in the wood of dying or dead

1 Maintained at Berkeley, California, in cooperation with the University of California.

Douglas-fir trees. They are known to be able to survive and to continue to develop in recently cut lumber from such trees, even after it has been used in buildings. Because the adults and larvae of this beetle occasionally bore holes through floors, ceilings, walls, and roofs of new structures, they sometimes are a problem to lumber suppliers, builders, and home owners (Eaton and Lyon, 1955).

Emergence in buildings has almost invariably been reported as occurring within a year after the buildings were constructed. One might infer that the beetles all complete their development in a single year. This is contrary to what we know or suspect about the insect's life span in nature. Kimmey and Furniss (1943) report that the beetles, normally, probably take several years to reach maturity. A more plausible explanation for the absence of the beetles in buildings after the first year is that the environment becomes unfavorable for those that are unable to mature in this period. Consequently they die.

In their natural environment *A. productus* beetles develop in fairly moist wood. In buildings constructed with infested lumber that is green when first used, the drying that takes place would result in conditions quite different from those of wood still in the tree in the forest. These conditions probably would tend to deter larval development, and it is conceivable that only the more fully developed individuals would reach the adult stage. Some support for this belief was found from observations on the survival of a few larvae in lumber kept indoors at Berkeley, California, over a 13-month period.

In November 1955, two pieces of infested Douglas-fir, about 2 inches by 4 inches by 4 feet in size, were obtained from recently cut fire-killed trees near Jenner, Sonoma County, California. When brought indoors, the wood was very moist, prominently bluestained, and well riddled with roundheaded-borer galleries. The larvae were located by cutting along their galleries through the wood. After their size and condition were noted, the larvae were sealed in their galleries with black masking tape. The tape was removed briefly at intervals of one to two months so that the condition of the larvae could be observed.

Eight larvae were found in the two pieces of lumber. One additional larva escaped detection, but was discovered when the wood was split up in September 1957. The larvae were kept under

observation from November 16, 1955 to December 27, 1956. At the beginning of this period they were thought to be between one-half and three-fourths grown. However, head-capsule measurements of those that died revealed that all but one were of the same size, presumably full grown.

Only one of the eight larvae completed its development. The remainder died at various lengths of time after observations were begun. The one individual that survived was a male that emerged as a full-grown beetle at seven months. Of those that died, one succumbed after one month, one after four months, three after seven months, one after ten months, and one after thirteen months.

The moisture content of green Douglas-fir sapwood is normally 100 per cent or more of its oven-dry weight. However, under indoor conditions, such as those in which the samples were held, moisture content would gradually decrease to the level commonly reached in buildings in this area, i.e., about 10 per cent. During the early part of the observation period, when the samples were still fairly moist, most of the larvae continued their mines. However, as the wood dried, they became less and less active. The frass they produced, which is normally fairly coarse, became very fine. The larvae, instead of increasing in size, became smaller so that in death their corpses were mummified. These observations suggest that the wood became too dry for the larvae to survive, and that they died from dessication. When infested lumber is used in buildings, many larvae probably suffer the same fate. This may explain why *A. productus* damage is seldom reported beyond the first year after construction.

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Kimmey, J. W. and Furniss, R. L.

1943. Deterioration of fire-killed Douglas-fir. U.S. Dept. Agr. Tech. Bul. 851, 61 pp., illus.

A PREOCCUPIED NAME IN SOLIERELLA

(Hymenoptera: Sphecidae)

Solierella prosopidis Williams, new name, is proposed for *Solierella mandibularis* Williams. *Solierella mandibularis* Williams (Pan-Pac. Ent., 34:212, 1958) is preoccupied by *Solierella mandibularis* de Beaumont (Bull. Soc. Sci. Nat. Phys. du Maroc, 36:147, 1957).—Francis X. Williams, *La Mesa, California.*